Ecosystem-Based Assessment of the Koksilah River Watershed

Phase 3 Report: Protected Networks

Photo Credit: Todd Carnahan

Submitted to:
Cowichan Station Area Association

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Acknowledgements

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Limitations and Application of Results

Certain limitations affected the accuracy of the accompanying maps. Most of the watershed is privately owned, and detailed data on terrain, forest age, wildlife, plants, water, and other values are not available for our assessment of the Koksilah River watershed. Private land ownership also limited access for field study. We relied on publicly available data and information shared by Cowichan Tribes community members, settler community members, and landowners to develop content in this report.

Information may improve in coming years, through new data and/or shared information. While some of the mapped line work may change, the rationales for including the various landscape features in the network are not expected to change.

The protected network identified in this report is not linked to any legislation and therefore has no legal basis. Rather, the intent is to inform residents and landowners about a possible approach to protect and restore the ecological integrity of the watershed.

Introduction

This report provides the context and rationale for a network of protected areas designed for the Koksilah River watershed (Figure 1) and commissioned by the Cowichan Station Area Association. This phase 3 is the final step towards completing an *Ecosystem-based Assessment of the Koksilah River Watershed* ('the Project'). The objectives of the Project are: i) to prepare an ecosystem-based assessment of the Koksilah River watershed applying the principles and methods developed by the Silva Forest Foundation and Silva Ecosystem Consultants (Hammond 2002; Silva Forest Foundation 1997, 2009); ii) to ensure the Project addresses questions of interest to the Cowichan Tribes community, and, where permitted, includes local and traditional knowledge shared by Cowichan Tribes community members; iii) to maximize community participation in the project, including the inclusion of local knowledge; and iv) to provide tools, such as the ecosystem-based planning methodology and maps, for building local capacity in ecosystem-based management in the Koksilah River watershed, and encourage wider use throughout the Cowichan region.

In Phase 1 of the Project, we used publicly available data and relevant literature to describe the original character of the watershed (i.e., pre-industrial human activity) as well as its current condition (Pritchard et al. 2019). Phase 1 products included: 1) a report describing the character and condition of the Koksilah River watershed, 2) a set of thematic maps to aid in the description of the watershed's character and condition, and 3) a geodatabase of spatial data used to produce the thematic map set.

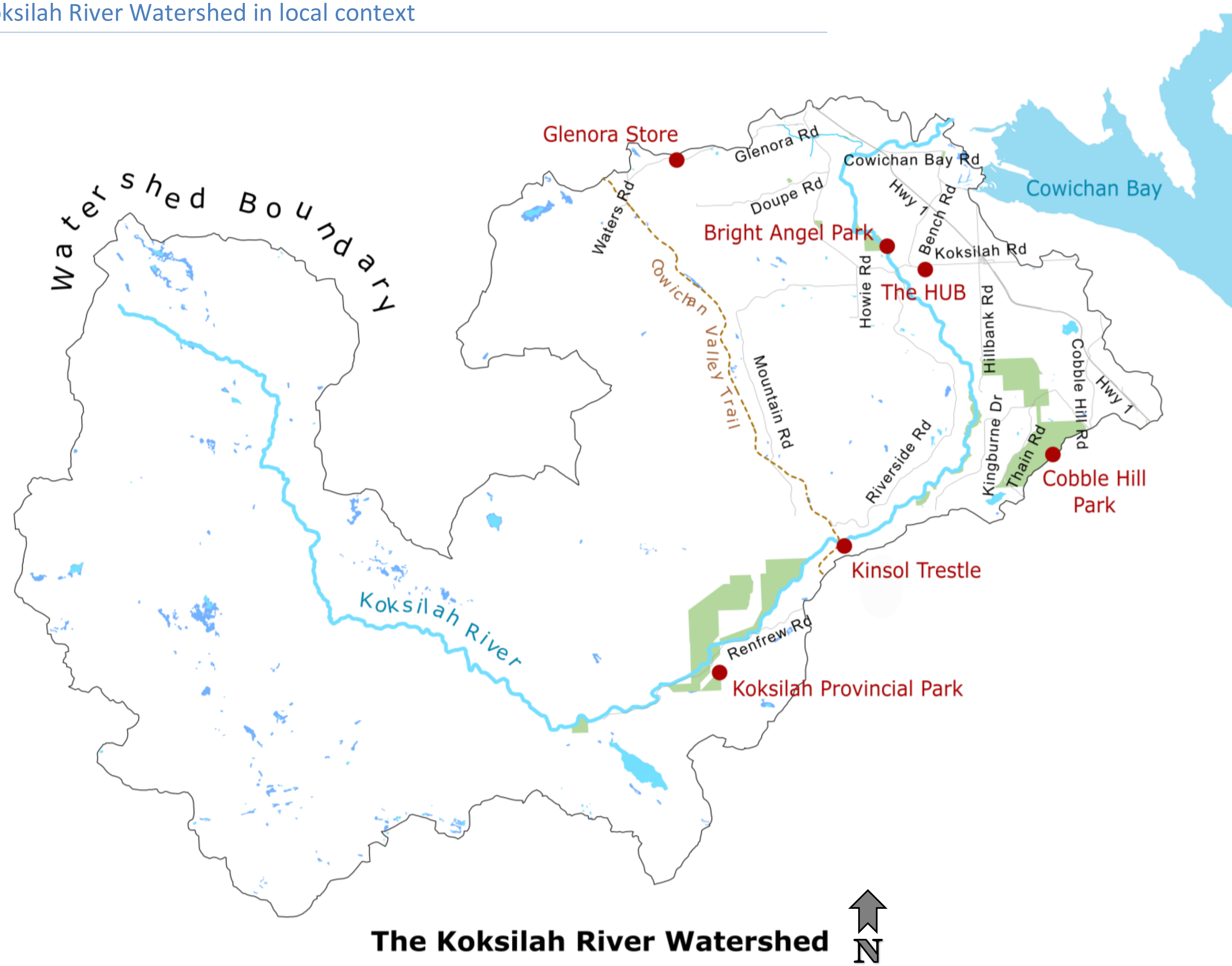
In Phase 2, we conducted a community review of the maps and information produced during Phase 1, soliciting and integrating feedback from Quw'ut'sun elders and community leaders, Cowichan Tribes staff, and non-Quw'ut'sun settler community members.

The final stage of the Project, Phase 3, is the focus of this report. Drawing from information gathered in Phase 1 (description of watershed character and condition) and Phase 2 (community review), the goal of Phase 3 is to design a multi-spatial scale network of protected areas for maintaining and restoring ecological integrity in the Koksilah River watershed. More specifically, this includes developing:

- a proposed Protected Area Network (PAN) for the Koksilah River watershed as a whole;
- a proposed Protected Landscape Network (PLN) at the sub-watershed scale; and
- an example of a Protected Ecosystem Network (PEN) at the site-scale.

A more detailed description of the approach used to develop the network of protected areas is provided below.

Figure 1. Koksilah River Watershed in local context



Approach

Establishing ecological networks to protect biological diversity and ecosystem functioning is not a new concept. In their 2006 report, the United Nations Secretariat of the Convention on Biological Diversity (CBD) provides a comprehensive review of ecological network case studies dating back to the early 1980s and spanning several continents (Bennett and Mulongoy 2006). Despite differences in terminology to denote ecological networks, the CBD points to common characteristics amongst all cases reviewed, including the consideration of multiple spatial scales, and the integration of a mixture of "core areas", corridors, buffer zones and "sustainable-use areas" (Bennett and Mulongoy 2006). The Koksilah River watershed ecological network, herein referred to as the "network of protected areas", grows from these same roots.

The specific approach used to develop the network of protected areas is based on the ecosystem-based conservation planning methods developed by Silva Ecosystem Consultants and the Silva Forest Foundation (Hammond 2002; Silva Forest Foundation 1997, 2009, undated), in which ecological integrity is positioned as the precursor to developing healthy communities and economies. In other words, we take an ecosystem-based approach to designing the network of protected areas. Like the ecological network concept, the "ecosystem approach" has also earned esteem by the CBD for enabling " holistic decision-making and action", and is the officially adopted framework for implementing the CBD (Bennett and Mulongoy 2006). Thus, we are in good company when guided by the principles outlined below.

The ecosystem-based conservation planning (EBCP) principles developed by Silva Ecosystem Consultants and the Silva Forest Foundation are as follows (Hammond 2015):

Principle 1: Focus on what to protect, then on what to use.

Principle 2: Recognize the hierarchical relationship between ecosystems, cultures, and economies.

Principle 3: Apply the precautionary principle to all plans and activities.

Principle 4: Protect, maintain, and where necessary, restore ecological connectivity and the full range of composition, structure, and function of enduring features, natural plant communities, and animal habitats and ranges.

Principle 5: Facilitate the protection and/or restoration of Indigenous land use.

Principle 6: Ensure that the planning process is inclusive of the range of values and interests.

Principle 7: Provide for diverse, ecologically sustainable, community-based economies.

Principle 8: Practice adaptive management.

Applying the Principles

These overarching principles articulate the values we have attempted to uphold in designing the network of protected areas. In order to fulfill Principle 4, the network of protected areas must be designed at multiple spatial scales. This means considering the inclusion of a proposed protected area for its significance at the site-level, as well as for its role in a broader (i.e., whole watershed) context. For the Koksilah River watershed we have focused primarily on developing a proposed network of protected areas at two spatial scales:

1) Protected Areas Network (PAN)—larger reserves and linkages that facilitate ecological integrity at a whole watershed scale

2) Protected Landscape Network (PLN)— smaller reserves and linkages that facilitate ecological integrity at a sub-watershed scale

It is important to note that neither the proposed PAN nor the PLN exclude human activities that maintain the composition, structure, and function of ecosystems, such as Indigenous land use and wildcrafting (Hammond 2015).

Site-Scale Application

To address ecological integrity at the site scale, we provide an example of a Protected PEN. A PEN includes additional smaller features that may not have been identified at coarser scales (i.e., in the PAN or PLN), but are no less important to the composition, structure and function of the watershed. PEN features requiring protection are identified in the field, such as small riparian ecosystems or mineral licks, and appropriate buffers are applied. Remaining areas are then available for human uses conducted in an ecologically responsible manner. Depending on the site, and the manner of implementation, such human uses might include timber management, non-timber forest products, and tourism.

Key principles guiding human use include ensuring diversity in land use while maximizing the number of people who benefit from the products and services produced (Silva Forest Foundation 2000). When developing PENs, we refer to more activity-specific standards for guidance, including the Standards Checklist for Ecologically Responsible Timber Management (Silva Forest Foundation 2000).

Ecosystem-based conservation planning is an approach to land management that recognizes that important ecosystem services, such as clean water, wildlife habitat, and spiritual value, exist across land ownership boundaries. That is, land ownership brings with it a level of responsibility to carefully consider all values for all of life that depend upon them. Also, ecosystem-based conservation assessments are intended for ecologically derived boundaries (Holt 2001), for example, the Koksilah River watershed boundary. Therefore, to a reasonable extent, we have ignored land ownership and administrative boundaries when establishing the protected network.

Focusing on Restoration

Since over 98% of Koksilah River watershed has been disturbed in recent decades (Pritchard et al. 2019), the network of protected areas focuses significantly on restoring ecological integrity. For the purpose of the Project and the Phase 3 report, we refer to restoration as "*assisting natural processes [to] re-establish the natural composition, structures, and functions at all scales*" (Silva Forest Foundation 2000). Collectively the PAN, PLN, and PEN have been designed to work together to restore ecological integrity at all scales, including:

- Protecting and restoring old growth structures (e.g., large, dead, and decaying trees);
- Increasing mature and old forest cover as well as interior forest conditions (i.e., larger patches of mature and old forest);
- Restoring and protecting riparian forests; and
- Restoring and protecting natural drainage patterns.

Overview

This report consists of two parts: Part 1 describes the proposed PAN and proposed PLN, which are designed at the watershed, and sub-watershed scales, respectively. Recommendations for the PAN and PLN are prefaced by a description of each feature included in the design, and their respective contribution to the overall intent of the full network of protected areas.

Part 2 describes the proposed PEN, designed for the site-scale, and includes examples of protective and restorative actions that can be taken by community members and individual landowners. A summary table organizes PAN- and PLN-level recommendations by target audience: forestry, agriculture, residential, and local government.

The recommendations provided in this report offer a foundation for the development of an ecosystem-based watershed management plan, whose actions are guided by ecological boundaries and give due attention to watershed health at multiple spatial scales.

Part 1: Proposed Protected Area and Landscape Networks

The proposed PAN creates moderate to large-sized protected areas and linkages that extend across the Koksilah River watershed. The overall goal of this network is to capture the remaining ecological diversity in the watershed and to provide a baseline level of connectivity (Hammond 2015). In ecological literature, connectivity is defined as "the degree to which the landscape facilitates or impedes movement among resource patches," (Taylor et al. 1993), and connectedness refers to structural or physical connections between patches or nodes (Rudd et al. 2002). Thus, through greater connectedness (i.e., physical connections via protected networks), greater connectivity (movement of species, genetic material, resources, etc.) is achieved.

The proposed PLN works at a finer scale, connecting smaller protected areas within the sub-watersheds (e.g., Glenora Creek). The goal of this network is to protect smaller reserve areas featuring unique structures (e.g., small patches of old growth), ecologically sensitive areas not already captured in the PAN (e.g., rare ecological communities), and create linkages between these features and with the PAN (Hammond 2015).

Specific Objectives of the PAN and PLN

During Phase 1 of the Project, pressures were identified in the watershed that put various degrees of stress on certain ecological values. In particular, commercial forestry activities and land clearing for agriculture and settlement have altered forest cover on 98% of the landbase; an extensive road network interrupts natural water flow patterns throughout the entire watershed; and agricultural and industrial development has resulted in large water withdrawals concentrated within the lower watershed, especially during the dry summer months (Pritchard et al. 2019). Observed changes in the watershed include very low summer flow rates, declining water quality, loss of habitat structures for fish and wildlife, and increased flooding in lower stream reaches.

The long-term objectives of the PAN and PLN are to protect and restore ecological integrity at multiple spatial and temporal scales, and in particular, to:

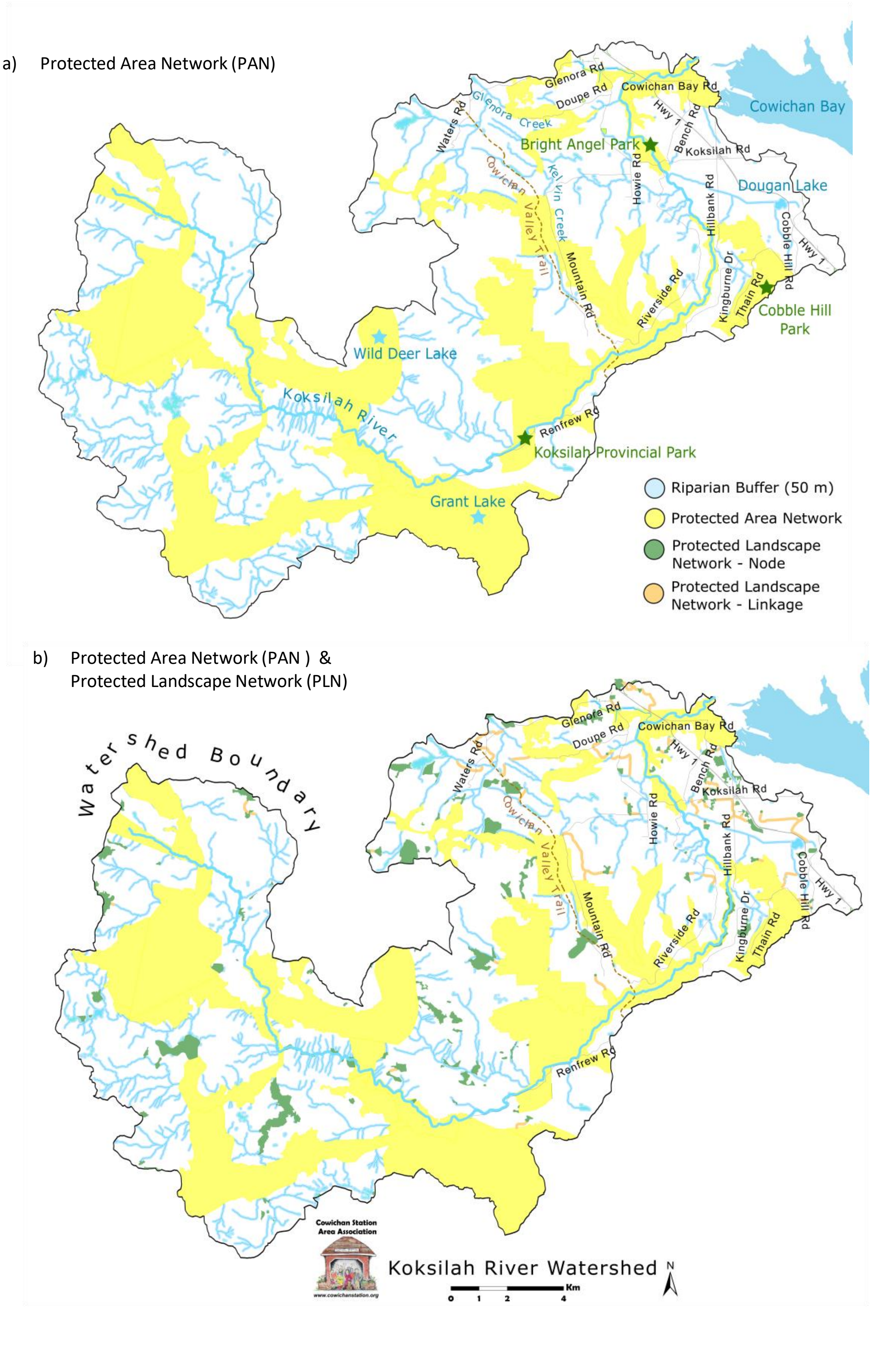
- Restore hydrologic functioning:
  - Address water yield and low flows in dry summer and early fall months
  - Moderate "flashiness" linked to industrial human activities and exasperated by climate change
  - Maintain cool water temperatures and low turbidity levels
  - Protect water quality of ground and surface water
- Protect and restore habitat for sensitive wildlife species, plants, and ecological communities
- Protect and restore habitat for broad species groups (e.g., cavity nesters)
- Restore aquatic habitat for fish
- Protect and restore soil microorganisms and soil productivity
- Protect and restore landscape connectivity

Protecting and restoring ecosystem composition, structure and function at multiple spatial and temporal scales, considers the range of natural variation—the naturally dynamic nature—

inherent to the watershed's character. Not only does the development of ecological features and functions vary over time and space, but recovery periods following disturbance can also vary substantially. Sutherland et al. (2016) found that ecosystem services that arise from ecological functions, such as wild berries and coarse woody debris are available almost immediately after logging, but then decline and can take decades to recover. In contrast, nesting habitat for old growth forest-dependent species, such as the Marbled Murrelet (*Brachyramphus marmoratus*), and large (>1m) western redcedar trees can take 100+ years to recover. In the case of the latter, the recovery timeline can extend to over 200 years (Sutherland et al. 2016). Vastly different in their response to disturbance, each of these ecological features plays an essential role in maintaining a watershed's ecological character. Protection and restoration efforts must therefore span the full spectrum of time and space—from backyard to basin, from one year to one generation, and beyond.

In designing the PAN and PLN (Figure 2), we focus heavily on restoration opportunities due to the extent of forest alteration from logging and land clearing. Although it is preferable to include extensive undisturbed forest in the network of protected areas, this is not possible in the Koksilah River watershed.

Figure 2. Features of all sizes are protected in this multi-scale network of protected areas.



Protected Area Network

The components that comprise the PAN include

1. Parks and protected areas,
2. Steep slopes and/or shallow soils,
3. Riparian ecosystems, and
4. Areas that connect the previously-listed features to form landscape linkages.

Using information from Phase 1, existing ecological features were selected to provide anchors, or starting points, for designing the PAN, as they are unique (e.g., critical habitat for species at risk) and/or in short supply (e.g., old growth forest). Below, we discuss each feature and its importance in greater detail, as a rationale for inclusion in the PAN.

PAN - Parks and Protected Areas

Definition: All provincial and regional parks greater than 0.5 ha, as well as recreation sites were included in this category.

This includes: Koksilah River Provincial Park (including the new Eagle Heights addition), Bright Angel Regional Park, Cobble Hill Mountain Regional Recreation Area, Kinsol Trestle trail recreation site, Bonanza Bluffs recreation site, Koksilah Pools recreation reserve, Busy Place Creek Park, Keating Park, Kingburne Park, Maple Grove Park, and Maplewood Park.

Some of these parks are very small regional parks that are captured in larger protected features such as riparian buffers or landscape linkages.

Rationale: Although some of these parks have considerable human use, they are included in the PAN because they offer some long-term protection of certain important features such as riparian forest, older mature and old growth forest, and habitat for wildlife, plant species and ecological communities, including threatened or endangered species. All the parks and recreation sites occur in the highly impacted Coastal Douglas-fir (CDFmm) and driest Coastal Western Hemlock (CWHxm) ecosystems. For example, Koksilah River Provincial Park protects moist riparian forest along the river as well as a dry upland grassland meadow in Eagle Heights. Cobble Hill Mountain Regional Recreation Area protects a significant area of the BC Red-listed Douglas-fir / dull Oregon-grape ecological community. While the current value of the smaller parks is questionable, they do present possible opportunities for establishing rain gardens, native plant gardens, and other restoration features.

PAN - Steep Slopes and/or Shallow Soils

This component of the PAN includes areas with potentially sensitive soils such as steep slopes and/or shallow soils. Other sensitive terrain features, such as karst, and bedrock outcrops are addressed in subsequent sections of this report.

Steep Slopes

Definition: This category includes terrain features mapped during Phase 1 as having a higher potential for movement. This includes: i) areas mapped as slopes greater than 60% with surficial material classified as one of: colluvial veneer, colluvial veneer blanket, glaciomarine blanket, or moraine blanket; ii) all areas classified as organic blanket with the potential for rapid mass movement; iii) all areas mapped as gullied moraine blanket; iv) all areas mapped as gullied fluvial steep slope; and v) all talus slopes.

Rationale: The conditions described above generally indicate a higher potential for surface soil erosion and/or landslides (Province of British Columbia 1999; Howes and Kenk 1997). The surficial materials listed here are highly erodible types found in the watershed and are more susceptible to movement on steeper slopes, especially where surface water is present. Gullied terrain tends to concentrate surface water and increase the energy that causes erosion, particularly once forest cover is removed. Gullies are also often connected directly to streams, resulting in eroded sediment or vegetative debris flowing directly into waterways instead of settling out onto the forest floor.

Shallow Soils

Definition: This category includes areas mapped during Phase 1 as veneers, which are thin layers of soil usually between 10 cm and 1 m thick (Howes and Kenk 1997).

Rationale: These areas are usually drier and less productive growing sites. Growth rates of trees are slower and plant communities on open sites are fragile. Consequently, recovery from disturbance can be very slow. For example, the arbutus-hairy Manzanita (*Arbutus menziesii/Arctostaphylos columbiana)* plant community is BC Red-listed and is found in drier, low-mid elevation areas. Its natural range is very small and restricted to southern coastal BC, and hairy manzanita in particular is slow-growing (Cadrin and Yearsley 2013). As a result, it can take quite a long time for this rare plant community to recover from disturbance. Habitat loss due to urban development or other land uses, as well as invasive grass species would make recovery even more difficult.

PAN - Riparian Ecosystems

Riparian ecosystems protect aquatic and terrestrial values extending from low to high elevation areas in the watershed. Riparian ecosystems have been divided into two categories: i) rivers, creeks, wetlands, lakes, and springs; and ii) riparian habitat.

Riparian ecosystems provide a wide range of functions that are critical to a healthy watershed. For example, lakes, wetlands and ponds act as water storage, recharge, and flood mitigation zones. Riparian areas also act as water filters and can prevent contamination of groundwater and drinking water sources. Wetlands help to recharge aquifers, offer flood protection, help maintain base flows, and maintain water quality (Wetland Stewardship Partnership 2009).

Rivers, creeks, wetlands, lakes, and springs (aquatic values)

Definition: A 50-meter buffer was established on both sides of river and creeks, as well as around wetlands, lakes, and licensed springs, consistent with the 50-meter buffer on either side of a stream recommended by the Silva Forest Foundation (2000).

Note: Some water bodies (e.g., wetland complexes) are captured in larger protected network features such as Landscape Linkages, and are discussed in relevant sections below.

Rationale:

Riparian ecosystems provide many ecological functions as summarized in a literature review by Carver (2001). Here we describe those functions independent of plant and wildlife habitat, which is described in the following section.

The 25-meter zone adjacent to the watercourse is important for protecting bank stability. The roots from living trees and shrubs hold soil in place reducing sediment entering the stream and create overhangs that provide cover for fish and other aquatic species.

In the zone up to 50 meters, or one tall tree height from the watercourse, some of the large conifers will eventually fall into the river or stream. By slowing down water, these dead submerged trees trap sediment in the water and help to stabilize channels especially during winter storms. Vegetation and a healthy forest floor slow down surface water during storms, allowing water to infiltrate into the soil and sediment to deposit on land instead of in the water.

Riparian ecosystems in the 50-meter zone also play an important role in regulating stream temperatures. Stream temperatures can naturally increase downstream even when there is overtopping vegetation (Bladon et al. 2018). When forest cover is removed however, water temperatures usually increase, sometimes quite significantly. Retaining intact forest cover downstream can rapidly cool water temperatures such that there is little to no difference in temperature, even when compared to pre-forest harvest temperatures (Bladon et al. 2018).

In the Koksilah River system, retaining downstream forest cover is especially important in areas where streambeds consist of permeable sands and gravels, which allow cooler groundwater to enter warming streams. Given that summer stream temperatures in the river system have increased somewhat in recent years (Pritchard et al. 2019), maintaining riparian vegetation, particularly in lower stream reaches, becomes particularly important as temperatures increase with climate change.

Photo 1. The 50 meter buffer along a watercourse protects bank stability, moderates stream temperature, provides insects for fish, and provides large trees and vegetation for fish cover (Photo credit: Barry Hetschko).

Riparian habitat (aquatic and terrestrial values)

Definition: Riparian habitat includes two features, the 50-meter buffer described above, as well as wider buffers known to provide specific or unique habitat.

For the Koksilah River watershed, we included riparian ecological communities at risk in this category. Although critical habitat proposed for Painted Turtle (*Chrysemys picta*) fits in this category, it is captured in "landscape linkages" described below.

Rationale: Trees, shrubs, and other vegetation within 30 meters (i.e., 0.6 tree heights) of a stream, wetland, or lake provide nutrient inputs for aquatic ecosystems (Carver 2001). Leaves and invertebrates fall into the water, providing food for fish, and other aquatic species.

The riparian ecosystems included in the PAN provide some of the most important and diverse habitats for wildlife as they include well-established herbaceous, shrub, and tree layers as well as coniferous, mixed, and deciduous forest patches with ample wildlife trees. Research indicates that the majority of vertebrate wildlife species occur in riparian areas, especially in the Coastal Douglas-Fir and Coastal Western Hemlock ecosystems (Bunnell and Dupuis 1995), both of which are prevalent within the watershed.

Wetlands are essential for amphibians such as the listed Western Toad (*Anaxyrus boreas*) and Northern Red-legged Frog (*Rana aurora*) as well as many songbird and waterfowl species. A minimum 35-meter buffer is required around wetlands to create forest conditions suitable for amphibians (Wind 2000). Amphibians and reptiles often require forest cover to connect small headwater streams to wetlands (Carver 2001). Mammals such as the keystone species American

Beaver (*Castor Canadensis*), Common Muskrat (*Ondatra zibethicus*), and bats are also highly dependent on wetlands. Bats extensively forage on water-borne insects that emerge from wetland ecosystems. Water quantity and quality of wetlands are therefore of great importance to wildlife.

Wider buffers provide additional protection for a range of different riparian habitat types. In the Koksilah River watershed, this includes rare ecological communities (e.g., black cottonwood – red alder / salmonberry) adjacent to streams in the lower watershed.

Riparian ecosystems are important landscape features for helping ecosystems adapt to changing climate (Krosby et al. 2018). The microclimates within riparian forests are cooler and moister, providing preferred conditions for species stressed in the warmer and drier conditions in their current habitat. Since the majority of forest-dwelling vertebrate species of ecosystems common to the watershed occur in riparian areas, riparian ecosystems become important dispersal corridors (Bunnell and Dupuis 1995). The most effective riparian corridors to help species migrate to areas with preferred conditions are wide, have dense canopy cover, and span a wide range of climatic conditions (Krosby et al. 2018).

PAN - Landscape Linkages

Definition: Landscape linkages enable broad lateral and elevational connections across a landscape, and provide adequate space for the protection of larger features. In the PAN for the Koksilah River watershed, we link remnant late successional forests, connect low and high elevation ecosystems, connect upland areas to riparian ecosystems, and connect slope faces across long distances.

Other specific ecological components included in the PAN landscape linkages include:

1. Karst formations,
2. Large wildlife habitat features,
3. Wetland complexes,
4. High vulnerability aquifers, and
5. Representative ecosystems.

Standards established by the Silva Forest Foundation (2000) require that landscape linkages are at least 300 meters wide, and, in larger landscapes, are ideally 2 to 5 kilometers wide. Linkages that are at least 600 meters wide provide 200 meters of interior forest conditions, buffered by 200 meters on all sides (Province of British Columbia 1995a). The location of these linkages is selected to avoid features, such as cliffs or deep gullies, that can impede the movement of large mammals (Silva Forest Foundation 2000).

Landscape linkages in the PAN were also designed to seamlessly extend those recommended as part of the ecosystem-based conservation plan for the neighbouring Shawnigan Lake watershed (Hammond 2015).

Rationale: Landscape linkages are the largest component of the PAN and PLN and are particularly important for their role in mitigating the impacts of climate change (Heller and Zavaleta 2009). Heller and Zavaleta (2009), in their review of 112 articles, found that linkages provide important spatial elements for climate change mitigation. Specific recommendations for creating linkages, drawn from Heller and Zavaleta's (2009) review, as well as recommendations drawn from other literature, include:

- Establish migration corridors across and along the range of elevations (Gayton 2008, Heller and Zavaleta 2009);
- Create networks of large reserves interspersed with small reserves (Heller and Zavaleta 2009);
- Increase the number of reserves and reduce gaps between reserves (Heller and Zavaleta 2009);
- Establish large riparian buffers up to three tree lengths wide (Carver 2001);
- Restore rivers and wetlands (Heller and Zavaleta 2009);
- Protect karst formations to ensure they maintain their ability to cool flowing water (Province of British Columbia 2003); and
- Reduce non-climate stressors such as extensive forest removal, habitat fragmentation, and excessive road building (Gayton 2008).

Karst

Including potential karst formations in the PAN may protect wildlife and plant species and their habitat, places with high cultural and/or historical value, downstream water quality and quantity, and fish productivity in lower stream reaches fed by water flowing through karst formations (Province of British Columbia 2003). While forests growing overtop karst tend to have higher growth rates because of the well-drained soils and extra release of soil micronutrients, karst terrain is highly sensitive as soil development is extremely slow. The BC Ministry of Forests characterizes karst as a "highly valuable, non-renewable resource" (BCMOF 1997).

Many wildlife species will use caves formed in karst as resting habitat while some plants are known to prefer the limestone and/or cool moist conditions for growing (Province of British Columbia 2003). Karst formations and their associated caves in the watershed could provide overwintering habitat (i.e., hibernacula) for Little Brown Myotis (*Myotis lucifugus*), a federally endangered bat species. Critical habitat established under the federal *Species at Risk Act* indicates that known hibernacula likely occur either in or near the Koksilah River watershed (ECCC 2018) and any known hibernacula must be protected, both on Crown and private land. Rock crevices are another terrain feature that may be inhabited by hibernating bats.

Karst formations benefit fish habitat in a wide variety of ways (Province of British Columbia 2003). Important to the Koksilah River system, water flowing underground is cooler which may help improve dissolved oxygen levels and maintain cooler water temperatures in summer for young salmon, including developing Steelhead and Coho fry. Invertebrates and algae, important fish food, benefit from the higher nutrient content of the water flowing through karst. Because of their ability to store water, karst formations can reduce the severity of low flows in dry summer months, affecting fish habitat as well as available water for domestic use.

Wildlife Habitat

A literature review by Beier and Noss (1998) investigated whether corridors (i.e., linkages) provide landscape connectivity for wildlife. They concluded that although scientific evidence is weak, landscape corridors are still a useful conservation tool (also Hobbs and Saunders 1990). Landscape linkages may provide key habitat elements for certain wildlife species groups including wide-ranging species, old growth-dependent species, and wildlife tree users, as well as support gene flow and dispersal.

Photo 2. Great-horned Owls commonly occur in the Koksilah watershed (Photo credit: Barry Hetschko).

Landscape linkages provide daily and seasonal travel and migration corridors for wide-ranging animals such as deer and elk, bears, and wolverine. Sutherland et al. (2000) summarized natal dispersal distances (distance traveled from birth site to breeding site) for many species and found high variability in distances traveled. Deer and elk travel between 2 and 18.5 kilometers. Male American Black Bears (*Ursus americanus*) have been documented to travel up to 225 kilometers while female bears tended to travel shorter distances, up to 28.5 kilometers. Wolverine (*Gulo gulo*) have been known to travel 300 kilometers from their birth place. Although these species do not require forest canopy consistently across the entire distance, predictable availability of accessible forest cover, water sources, forage or prey provided by linkages is important.

The landscape linkages also integrate the Critical Habitat polygons designated under the federal *Species at Risk Act* for Dun Skipper (*Euphyes vestris*), Marbled Murrelet, Northern Goshawk (*Accipiter gentilis laingi*), and most of the proposed Critical Habitat for Painted Turtle. Dun Skipper habitat includes wetlands and meadows (COSEWIC 2013a) -- two habitat types included in the PAN landscape linkages as well as in the PLN described below. Marbled Murrelet is a seabird species that nests inland and requires tall, large-branched, mossy old growth trees for nesting, preferably located within 30 kilometers of saltwater (COSEWIC 2012). Most of one Marbled

Murrelet Critical Habitat polygon was not included in the landscape linkage as it is almost entirely very young forest. Instead, mature forest sections within the excluded polygon were protected in the PLN. An adjacent Northern Goshawk Critical Habitat polygon with mature forest was included in the landscape linkage and may also provide Marbled Murrelet habitat. The Northern Goshawk shows preference for large mature to old growth forest patches (i.e., >100 hectares) with dense multi-layered canopies and scattered large live and dead trees (COSEWIC 2013b). The goshawk is known to prefer interior forest conditions as habitat, and avoids forest edges of young and cut stands and open areas.

Landscape linkages that include old forest habitat provide the structures required by wildlife tree users—for example, large dead and dying trees, dead fallen trees, hollow logs, shrubs, and multi-layered canopies.

Wetland Complexes and Grant Lake

Major wetland complexes (i.e., two or more wetlands that are connected) and the Grant Lake watershed are included in "landscape linkages" to help protect water storage capacity in the watershed. Wetland complexes and lakes capture and hold rainwater and snowmelt and regulate flow into streams and groundwater—particularly important for lower stream reaches during dry summer months. Much of the Grant Lake watershed is already included within a landscape linkage due to the presence of steep, gullied terrain and Critical Habitat for the Marbled Murrelet.

Photo 3. Wetland complexes in the Koksilah watershed are valuable for water storage and wildlife habitat.

In addition to storing water, wetland complexes within landscape linkages also provide large areas of interconnected habitat important to many wildlife species. Large areas of terrestrial habitat around wetlands are critical for maintaining wildlife, in particular as feeding, overwintering, and nesting habitat for reptile and amphibian species (Semlitsch and Brodie 2003). For example, the Northern Red-legged Frog, a known resident of the Koksilah River watershed (see Pritchard et al. 2019), benefits from landscape linkages that connect wetland complexes to upland habitat. Exposed clearcuts near wetlands are barriers to migration and dispersal as they lack moist microclimate provided by dense forest canopy and abundant dead trees (Wind 2000). Amphibian travel distances can be considerable, ranging between 500 meters for juvenile dispersal and 4.8 kilometers for adult migration (COSEWIC 2015). Other functions provided by wetland complexes include regulating microclimate and removing pathogens and pesticides from water (Cox and Cullington 2009).

High Vulnerability Aquifer

Most of the "high vulnerability" aquifer, which follows the lower reaches of the Koksilah River (see Pritchard et al. 2019), is included within a landscape linkage. Areas where this aquifer underlies heavily modified industrial and dense residential areas were excluded from the PAN, as there are no large features in these areas that have any semblance to their pre-industrial condition. Smaller features that have been restored or are less heavily altered were captured in the PLN, however.

According to the provincial classification system for aquifers, a "high vulnerability aquifer" has high potential for degradation should a surface spill occur (Berardinucci and Ronneseth 2002). This is because of the porous sands and gravels that make up the substrate of the aquifer. This aquifer is also classified as having a high demand for water relative to water availability.

Provincially, protecting water quality in high vulnerability aquifers is a high priority. In the Koksilah River watershed, much of the area overtopping the high vulnerability aquifer has been developed for agriculture, industry, and residential use. Placing this area within a landscape linkage highlights the importance of restoring this area whenever possible to reduce potential for groundwater contamination.

Representative Ecosystems and Structural Stages

Representative ecosystems are used to create linkages between individual polygons described above. Landscape linkages within the PAN connect all ecosystem types including the low elevation Coastal Douglas-fir, mid-elevation Coastal Western Hemlock, and high elevation Mountain Hemlock types. Although all age classes within these ecosystems are considered, older and mature forests are targeted for inclusion in landscape linkages as they are underrepresented in the landscape compared to historical conditions (Pritchard et al. 2019). Over time, allowing small remnant forests to age will help to increase the structural diversity in the watershed, which may take upwards of 200 years to develop.

Protected Landscape Network

The features listed above comprise the PAN -- a network of protected areas designed to capture and connect important medium and large-size areas across the watershed landscape. At a finer (sub-watershed) scale, the smaller patches and linkages included in the PLN fill in gaps and further increase landscape connectivity between those areas included in the PAN. The result is a complex web of features, designed to include the full range of representative, rare and sensitive ecological characteristics of the Koksilah River watershed.

The components used to make up the PLN include a variety of "nodes", or patches, and connecting linkages. Each of these, and the rationale for their inclusion, is discussed in their respective sections, below.

PLN - Protected Nodes

Definition: Protected nodes are strategic locations within the PLN that contain small ecosystem patches not previously captured at the scale of the PAN, including representative, unique and/or sensitive ecological features. In the Koksilah River watershed, this includes:

1. Old growth forests, old growth recruitment areas, and remnant forests in agricultural, industrial and/or residential areas (including riparian forests in the Coastal Douglas-fir biogeoclimatic zone)
2. Sensitive ecosystems, and
3. Areas surrounding licensed springs.

Rationale:

Nodes are particularly important in fragmented landscapes, such as the Koksilah River watershed, providing focal areas of habitat refuges to maintain and/or restore different aspects of biological diversity (e.g., species diversity, genetic diversity, structural diversity, etc.). While each species differs in the amount and quality of space it needs to survive, Rudd et al. (2002) argue that in highly fragmented areas such as cities, at least 0.5 ha is needed to fulfill basic habitat needs. While only the lower portion of the watershed is urbanized, all nodes were designed to be at least 0.5 ha in size. In urban and agricultural areas, some nodes include areas that have been altered by human activities. Restoration will be an important first step towards establishing these nodes. While larger and/or more closely located nodes function best (Linehan et al. 1995), connectivity between nodes is of equal importance (Noss 1983) and may compensate for smaller sized nodes in maintaining and/or restoring regional biodiversity.

Old Growth, Old Growth Recruitment Areas, and Remnant Forest

Small isolated patches of old growth forest and larger patches of maturing forest (40+ years) for old growth recruitment are included in protected nodes. As described above, old growth forests are under-represented in the landscape as compared to historical conditions and all patches need to be protected. Despite their size, small patches of old and maturing forest do have ecological value. The connectivity provided by small forested patches benefits many small bird and mammal species, for example, by offering protective cover for young that are leaving the nest (Sutherland et al. 2000).

Photo 4. This cross section is from a Douglas-fir that grew in the Koksilah River watershed. It reached 1300 years before it was blown down in 1962.

Ecologically Sensitive Ecosystems

Large areas that include steep slopes and/or shallow soils were included in the Protected Areas Network. Areas with the same characteristics, although smaller in size, were included in the PLN.

Licensed Springs

Approximately 64 licensed springs are located in the Koksilah River watershed, the majority of which are located in the lower watershed where agricultural, industrial and residential land uses dominate. Springs can be intermittent or perennial. They serve as a point of interaction between ground and surface water, posing risks to water quality and quantity should spring groundwater become contaminated, and/or natural surface or subsurface flows be disrupted. The source area of a spring is divided into a recharge area, where water infiltrates into the ground, and a discharge area where water moves up to the surface (Province of British Columbia 1996). While source areas are best delineated using an established technique, such as according to topography, geology, or water chemistry, designating an interim protection zone until a rigorous assessment can be made is also considered acceptable (Kreye et al. 1996). As with riparian areas, a 50-meter buffer was applied to surround all licensed springs.

PLN - Connecting Linkages

Definition: Connecting linkages are narrow corridors that link protected nodes to one another and to features in the Protected Areas Network. They are used to connect isolated features (e.g., small wetlands) and protected nodes to the larger network of protected areas. Connecting linkages have been designed to be 100 meters wide, consistent with the width of riparian buffers surrounding streams that also connect the watershed.

Rationale:

Nodes without linkages are unlikely to maintain all species and ecological processes (Province of British Columbia 1995). Some species are poor dispersers (e.g., flightless insects), a process that is further hindered by habitat fragmentation. Connectivity between patches in fragmented landscapes can more easily facilitate repopulation (Schippers et al. 1996), as well as prevent gene pools from becoming isolated and less diverse (Taylor et al. 2011). Not only do such linkages provide wildlife with access to food and shelter, they also provide cover from predators. For example, forest cover provides some protection (the degree to which varies with width of protected area) for migrating or dispersing amphibians (Wind 2000).

High quality habitat alone may not be enough to achieve conservation objectives. Isolated patches went unused by wildlife in one study, despite the suitability of the habitat (Hanski and Thomas 1994 in Rudd et al. 2002). The authors concluded that providing more, and a greater diversity of routes between suitable habitat patches for various species will increase the likelihood that habitat is used. Given the diversity and complexity of ecosystem interactions, and the near impossibility of predicting all movement patterns, increasing connections across the landscape is a practical step towards repairing ecological integrity in a fragmented landscape such as the Koksilah River watershed.

Linkage Features

While larger ecological features such as wetland complexes were captured in landscape-level linkages of the PAN, some smaller features such as individual wetlands remained isolated. Smaller scale connecting linkages were used to fill these gaps and protect or restore forest cover that joined these smaller features to a larger feature such as a watershed-scale landscape linkage, or a subwatershed-scale node.

In the lower Koksilah River watershed, linkages consist mainly of linear forest fragments scattered throughout agricultural and residential areas. The majority of these linkages are identified as mature forest. These linkages are particularly important as they have the potential to recruit old growth forest, as well as provide connectivity in areas where there are few opportunities for larger linkages due to zoning for higher density human settlement and more intensive use. In the upper watershed where there is a complex network of small streams, riparian buffers running along either side of these streams function as the fine scale linkages. Riparian linkages connect large linkages to each other, numerous wetlands, patches of old growth forest, and smaller areas with sensitive terrain.

Together, the PAN and PLN occupy over 42% of the Koksilah River watershed (Table 1). The PAN and PLN were established based on ecologically-based principles and there was no numerical target, however, the area protected within the network aligns well with targets in the literature established for Cowichan Valley ecosystems. In one study, it was recommended that 50% of the Coastal Douglas-fir ecosystems require conservation plans in order to protect and maintain ecological integrity (Holt 2007). In another study, it was determined that to maintain low risk to ecological integrity, 70% of the original area occupied by old forest under natural disturbance patterns, would need to be maintained (Price et al. 2007 and references therein). While it is uncertain how much of the pre-Contact landscape was old forest, we determined it was likely the dominant forest type occupying most of the watershed (Pritchard et al. 2019) and therefore our protected network is conservative by comparison.

Table 1. Area occupied by the PAN and PLN

	Area (ha)	Area (%)
Watershed	**31,171.8**	**100**
PAN	8,620.1	27.7
PLN-node	*963.0*	
PLN-link	*294.6*	
PLN total	1,257.5	14.6
Total	**9,877.6**	**42.2**

Part 2: Protected Ecosystem Network

Definitions

Of the three levels of protected areas proposed for the Koksilah River watershed, the PEN is the most detailed. It is designed to include the smaller features that may not have been identified for protection at coarser scales (i.e., at the watershed and sub-watershed scales), but which are no less important to the composition, structure and function of a watershed. Examples of PEN features requiring protection include small sensitive ecosystems, small or ephemeral streams, patches with high values wildlife trees, and remnants of mature forest, deciduous patches.

While the exact design for each PEN is site-specific, a PEN generally consists of two components:

1. A fine-scale network of protected areas (the make-up of which is described above) where most human activities are excluded, and
2. The ecologically responsible human use areas in between.

The term “human use” in this report largely refers to non-Indigenous contemporary land use. Traditional Indigenous land use has been widely recognized as a component of fully functioning ecosystems (Hammond 2002), and, unlike many contemporary approaches to conservation, involved integrating stewardship into all activities and all spaces that contributed to daily life.

Our discussion of human use in the PEN largely concerns contemporary uses, such as residential, industrial, agricultural and forestry uses. How these activities should be prioritized, and in what manner they are conducted, are important details for achieving ecologically responsible human use, and are discussed further, below.

Objectives

The overall objective of the PEN is to build on and complement the larger nodes and linkages of the protected areas by:

1. Locating missed elements, under-represented elements of biodiversity, under-represented structures, and small scale threats;
2. Providing small scale connectivity that links into PAN and PLN; and
3. Refining the PAN/PLN based on field observations.

Collectively, the PAN, PLN and PEN aim to restore fully functioning ecosystems and ecological integrity throughout the watershed, not just within reserves and linkages.

Where the PAN and PLN are like the foundation and frame of a house, the PEN is akin to the studs and joists. All pieces, big and small, are essential for building a stable, functional, and whole structure.

Human Uses

Not all human uses are equal in their ecological and, consequently, social and economic impacts. The legacy of some human uses (e.g., logging and agriculture) may temporarily or permanently preclude the existence of others, such as mushroom picking. To ensure all land users have equitable access to the land in order to meet their needs, the Silva Forest Foundation recommends that priority be given to human uses that are the least consumptive and aggressive, for which access to unmodified ecosystems is essential (Silva Forest Foundation, undated), and which benefit a diversity of users (Silva Forest Foundation 2000).

Most of the middle and lower portions of the Koksilah River watershed have been heavily modified. About 1% of the original forest in the watershed remains, and a substantive area has been converted for intensive use, such as large-scale farming, residential areas, and commercial and industrial activities (Pritchard et al. 2019). Small scale agricultural and forestry uses have also left their mark. Cumulatively, these human uses have led to significant changes in the ecological condition of the watershed. With this in mind, provided that efforts are coordinated and consider multiple spatial scales, there is no effort too small to matter in its protection and restoration. All watershed users have an opportunity to safeguard remaining fragments of the Koksilah's ecological character, and contribute to its incremental restoration, through direct land use and/or calling upon landowners and governments to uphold ecological accountability.

Below we present our recommendations for establishing a PEN and transitioning towards broad scale responsible human use within the watershed. We describe strategies that can be applied at the site level and within various land use contexts, to protect or restore ecological values and/or allow for ecologically responsible human use.

PEN Methodology

While developing the PAN and PLN is primarily a desktop exercise, designing a PEN is best done using site-specific information gathered in the field. Fieldwork aims to identify, for example, small streams, seasonal ponds and underrepresented elements of biodiversity including sensitive features and areas (e.g., wallows), underrepresented structures (e.g., large trees), and small scale threats (e.g., invasive plants).

In addition, field data collected for designing a PEN can be used to refine a PLN. For example, riparian corridors may be fine-tuned based on observed terrain features and plant communities. Riparian plant communities are useful indicators as to where soil and moisture conditions change, indicating a transition between riparian and upland ecosystems.

Given the logistical challenges of designing a PEN for the entire 30,000 hectare watershed, we focus instead on providing an example PEN for a small area that is representative of the range of land uses. The example PEN designates fine-scaled features requiring protection, as well as areas in which there should be, if not already underway, a transition towards ecologically responsible human use. General recommendations for how to achieve the vision described in the example PEN, are also provided.

Note: Due to the limitations imposed by the high degree of private land ownership and large number of individual landowners that would have to be contacted, we did not complete detailed fieldwork to design the example PEN. Instead, we made use of high resolution Google Earth imagery, supported by spot checks from public roads, to discern small-scale features of interest.

General Protected Ecosystem Network Recommendations

The following is a description of general recommendations for establishing a fine-scale network of protected areas within the Koksilah River watershed, as well as for transitioning towards responsible human uses in areas outside of protected zones.

Our recommendations are based on, and/or consistent with, those contained within the following documents, in addition to legal requirements and best management practices guiding land management in BC:

- Standards Checklist for Ecological Responsible Timber Management (Silva Forest Foundation 2000);
- Shawnigan Ecosystem-based Conservation Plan (Hammond 2015);
- Develop with Care (Province of British Columbia 2014); and
- Wetland ways: Interim guidelines for wetland protection and conservation in British Columbia (Wetland Stewardship Partnership 2009).

While it might appear that many of these recommendations can only be implemented or enforced by large landowners and/or government (e.g., re-establishing natural drainage patterns, avoiding further land conversion), all land users can contribute in some way. Small landowners can apply downscaled versions of these recommendations to their own property. Watershed users that do not own land can advocate for implementing these recommendations in discussions with neighbours, during community events, and with elected government officials. Implementing protection and restoration can take many forms, all of which contribute to the cumulative effect of positive change.

Recommendation 1: Abstain from any further logging of old growth trees or forest

Old growth forests, while historically common across the landscape, are now rare, occurring most often as narrow buffers along the Koksilah River and other watercourses (Pritchard et al. 2019). They are also rare throughout Coastal Douglas-fir and dry Coastal Western Hemlock ecosystems on Vancouver Island because of intensive land development (Price et al. 2020).

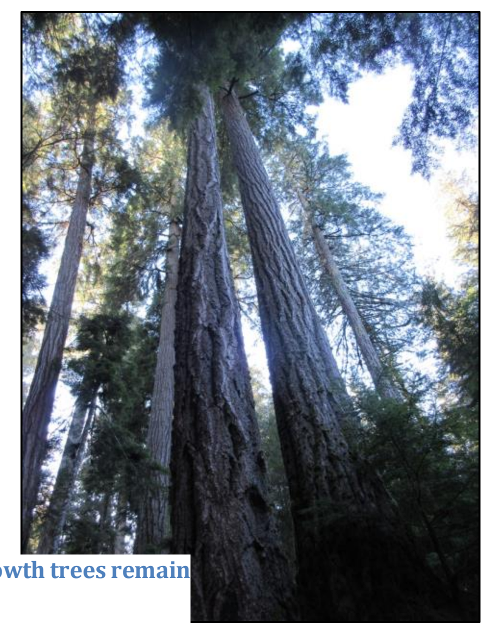


Photo 5. Few old growth trees remain in the watershed.

Although old forest functionality has declined in the Koksilah River watershed, there is still value in protecting remaining trees and patches. For example, remaining patches provide habitat for old growth dependent Marbled Murrelets, and single trees have value as "Mother trees" contributing to greater resilience to new trees for withstanding climate change (Suzanne Simard *in* Wohlleben 2015). Remaining old growth trees, and the diverse ectomycorrhizae communities they support, ensure that ectomycorrhizae readily re-establishes in neighbouring stands after they are harvested (Outerbridge et al. 2009).

Therefore, due to their low occurrence and high value, no additional old trees should be harvested.

Recommendation 2: Protect and restore all streams and water features, as well as any riparian ecosystems not already captured in the Protected Landscape Network.

All water features (e.g., streams, wetlands, springs, lakes, ponds) require protection in forested, agriculture, residential, and industrial areas. A default 50-meter buffer should be established when no field assessment is conducted (Silva Forest Foundation 2000). Alternately, buffers can be established during field assessments based on terrain features (e.g., changes in soils or slope) and natural vegetation complexes (e.g., changes from moist riparian to dry upland indicator species).

Measures to protect ecological integrity of the riparian ecosystem corridor include:

- Planning and conducting logging and land development away from riparian areas (up to 150 meters around wetlands in residential development areas (Wetland Stewardship Partnership 2009))
- Allowing low intensity partial cut logging only if windthrow hazard is low
- Excluding heavy machinery traffic from riparian ecosystems
- Abstaining from exposing mineral soil within 20 meters of a stream (preferably 30 meters)
- Retaining dead standing and fallen trees
- Excluding livestock from riparian ecosystems
- Abstaining from draining or filling wetlands and other wet areas
- Protecting wetlands from contaminated surface water runoff

In watersheds that are undeveloped or have minimal development, the intent is to ensure there is no land conversion (i.e., from forest to agriculture or residential) in riparian ecosystems (Silva Forest Foundation 2000). Because there has already been significant land conversion in the Koksilah River watershed, it is very important to protect remaining riparian ecosystems and restore those that have been impacted.

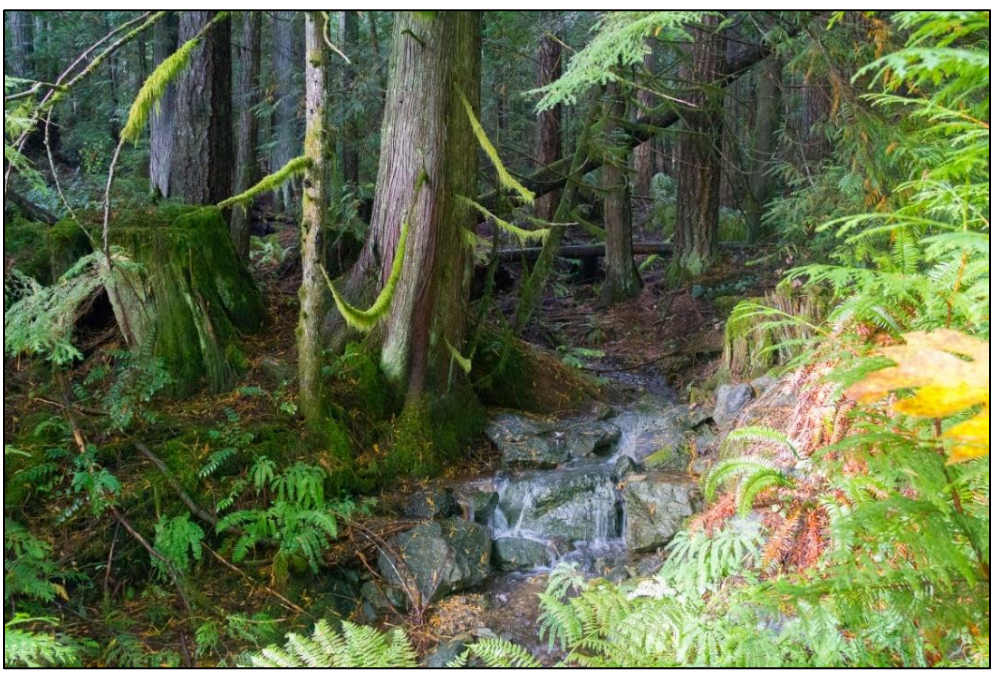


Photo 6. Small seasonal streams also require wide riparian buffers (Photo credit: Barry Hetschko).

Restoration activities should be implemented within disturbed riparian ecosystem corridors throughout the watershed, including:

- Planting or encouraging natural regeneration of tree and shrub cover in the riparian corridor
- Conducting live staking and/or plant trees or shrubs in streamside areas
- Using soil bio-engineering to stabilize eroding slopes
- Adding dead fallen trees to riparian ecosystems
- Removing invasive plants
- Removing ancillary buildings (e.g., small sheds) and other impervious structures
- Constructing wetlands
- Incorporating groundwater recharge features such as rainwater gardens and vegetated swales into areas where ecological condition is heavily modified

Recommendation 3: Incorporate full-cycle trees across the landscape.

Full-cycle trees are trees left to live out their entire life cycle, including dying naturally to become valuable snags and dead fallen trees, and then decomposing to become part of the organic soil layer. They provide many values such as wildlife habitat and large woody debris for streams, and are also very important for maintaining ectomycorrhizal communities necessary for making nutrients available to growing trees and for protecting trees from drought. Studies that include sample sites in and nearby the Koksilah River watershed (Outerbridge and Trofymow 2004; Outerbridge et al. 2009) have concluded that retained trees in harvesting sites are important for ensuring the recovery of ectomycorrhizae (Luoma et al. 2006).

In managed forests, 10-25% of dominant and co-dominant trees should be retained as full-cycle trees (Silva Forest Foundation 2000). Full-cycle trees should be selected to represent the natural range of species and sizes. Species should be selected to represent a range of successional stages while also considering climate change. For example, sites that, under pre-climate change conditions, were suitable for western redcedar, may not be able to support this species as summer drought conditions worsen.

For properties used primarily for agriculture, residential and industrial use, full-cycle trees can still be incorporated into land use planning and restoration. These trees will help to build connectivity and structure where development has heavily impacted the Coastal Douglas-fir ecosystem [1]. Although more challenging to plan for, full-cycle trees can be incorporated into these areas in the following ways:

- Retaining existing trees (especially large), singly or in clumps, wherever possible, to live out their full life cycle-- from living tree, to snag, to rotting wood;
- Protecting potential full-cycle trees in reserve areas if an area is being subdivided;
- Planting trees in restoration areas to recruit future full-cycle trees; and
- Establish tree protection laws and/or incentives that would protect full-cycle trees.

[1] See http://www.cdfcp.ca/index.php/about/why-is-the-cdf-at-risk

Recommendation 4: Retain existing large snags and dead fallen trees.

In managed forests, 1 to 3 large snags per hectare and 6 large fallen trees per hectare should be retained during logging (Silva Forest Foundation 2000). Alternately, the number retained could be based on estimates from any remaining old-growth patches. These retained structures should represent the range of species (deciduous and coniferous) and sizes (diameter and height), and include diversity in stages of wood decay (Bunnell et al. 1999). Highest value dead trees are larger than 50 centimeters in diameter, which benefit cavity-nesting species including Pileated Woodpeckers (*Dryocopus pileatus*), Red-breasted Sapsuckers (*Sphyrapicus ruber*), and Northern Flicker (*Colaptes auratus*) (Bunnell et al. 1999), as well as many mammals that occur in the Koksilah River watershed.

Old stumps in the watershed indicate that snags and dead fallen trees in second growth stands are significantly smaller than those of the original old-growth forests. Full-cycle trees described above will, over time, contribute to the creation of large valuable structures. However, until then, the retained smaller dead and fallen trees will still provide significant value.

At edges surrounding areas significantly modified by human use (e.g., shelterbelts dividing large agricultural fields), dead and fallen trees should also be retained. Some options for landowners and managers to consider include:

- Retaining dead trees wherever safe
- Tree-topping or high-stumping (3-5 meters) to create snags
- Retaining tops from topped trees on the ground to mimic dead fallen trees
- Hollowing out large logs to mimic rotted wood providing den cover
- Installing nest boxes for swallows, bluebirds and other cavity nesters
- Installing bat houses
- Creating Osprey platforms on topped trees near the ocean

Recommendation 5: Abstain from clear cut logging

Abstain from clearcut silvicultural systems, that is, from “remov[ing] an entire stand of trees from an area of one hectare or more and greater than two tree heights in width, in a single harvesting operation” (Province of British Columbia 1995b).

Clearcut harvesting is common practice in British Columbia forestry, and results in even-aged stands harvested every 40 to 80 years in the Koksilah River watershed (Pritchard et al. 2019). Often presented as an approach that mimics natural disturbance, that is not the case here, where stand replacing events such as wildfire historically occurred every 350 to 1,000 years depending on site conditions (Pritchard et al. 2019). Clearcut logging and land clearing have left most of the forests less than 60 years old, and only 1% older than 250 years. As noted in the character and condition assessment for the Koksilah River watershed, young forests transpire large amounts of water, which can lead to less water entering streams, less shade and moisture retention, and exasperated low water flows (Pritchard et al. 2019). Clearcut harvesting has and continues to create a landscape dominated by young, even-aged forests, and is inconsistent with restoration efforts to address the increased severity and frequency of droughts.

Recommendation 6: Avoid further land clearing in residential, agricultural and commercial/industrial areas.

Remnant forest fragments can provide a multitude of ecosystem services that benefit human activities, including:

- Shading our homes, yards and farm fields
- Increasing aesthetics and property value
- Keeping our soils moist during dry periods
- Hosting insects and animals that help us manage pests
- Protecting our crops and livestock from extreme weather
- Sequestering and storing carbon dioxide
- Intercepting rainfall to reduce stress on our storm drains, ditches, and septic fields
- Reducing odours
- Providing privacy

Existing residential, commercial and industrial areas should protect individual trees and patches as infill development is considered, with priority given to remnants that contribute to site-level ecological connectivity and have the opportunity to become full-cycle trees without compromising human safety.

New developments should, first, identify PEN-scale features to be protected (i.e., smaller clumps and/or individual riparian and other sensitive ecosystems, remnants of mature forest, deciduous trees, snags or wildlife trees, and ephemeral streams) then design settlement areas in a manner that accommodates these features.

When structured as shelterbelts, remnant forest fragments have been found to increase yields of sheltered crops, by providing protection from wind, increasing moisture retention, and improving pollination, with vegetables and alfalfa seedlings experiencing the greatest benefits (BC Agriculture & Food Climate Action Initiative, undated). Spacing between shelterbelts should be less than 10 times the shelter height (e.g., less than 250 meters, for a treed shelterbelt that is 25 meters tall) on the leeward side, or less than 3 times (eg. less than 75 meters) on the windward side (BC Agriculture & Food Climate Action Initiative, undated). Farms of all sizes should preserve existing shelterbelts surrounding areas under production, and look to establish new shelterbelts in large fields where none are currently present. Remnant forest fragments and existing shelterbelts were included in the PEN design; however, finer scale planning is needed to effectively capture the benefits of shelterbelts, and was outside the scope of this project.

Recommendation 7: Promote biologically diverse forests and agricultural lands.

During tree harvesting, emphasis should be placed on retaining or encouraging structural diversity in the landscape (i.e., layers of old and young trees, as well as shrubs and herbs), which can help maintain vertebrate species richness (Bunnell et al. 1999), the infiltration of water on site, and year-round retention of soil moisture. Forests, including those where harvesting has occurred, should consist of a range of tree and shrub species (coniferous and deciduous) with shade tolerant species growing beneath an overstory of taller trees.

Specific practices that will also contribute to vertebrate species richness and biological diversity include:

- Abstaining from removing trees or vegetation during wildlife breeding windows (see *Develop with Care* for breeding window dates (Province of British Columbia 2014))
- Surveying for active nests and protecting them when encountered, if forest harvesting (or any other tree removal) must occur during breeding windows
- Abstaining from burning piles (i.e., potential nesting sites) during breeding season
- Abstaining from herbicide use

Diversity can also be encouraged in agricultural scenarios, not only by retaining existing forest strips and patches, but also by adding additional vegetation layers between fields in the form of hedgerows or native plant strips. Native plant strips (often referred to as "prairie strips") are diverse native plant communities, established along field perimeters and in sloped areas. They have been shown to increase pollinator abundance and wildlife diversity, while decreasing surface water run-off and phosphorus transport to watercourses and into groundwater (Schulte et al. 2017). Relative to other regions of British Columbia, southern Vancouver Island contains some of the highest levels of terrestrial species richness (Caslys Consulting Ltd 2008 as cited in BC Agricultural Research Development Corporation 2010), presenting important opportunities for biodiversity to be protected as part of agricultural and forestry activities.

Numerous options for promoting biodiversity on farms are outlined in "Planning for Biodiversity: A Guide for BC Farmers and Ranchers" (BCARDC 2010). Some examples contained within this document are:

- Timing livestock grazing such that plants have sufficient time to regenerate, seed dispersal by invasive plants is minimized, and soils are not compacted
- Avoiding haying and mowing during seasons (e.g., breeding season) and times of day (e.g., early morning) when wildlife is most likely to be present in fields
- Maintaining water levels in ponds and wetlands during breeding season
- Seeding and grazing outside of breeding and nesting seasons
- Including perennial crops to reduce soil tillage and exposure of bare land
- Selecting crops and farming methods that are less reliant on chemical pesticides to produce strong yields
- Using cover crops to increase soil structural diversity and soil moisture holding capacity
- Removing invasive plants, particularly in riparian areas

Also, practices that retain maximum carbon in the soil promote healthy soils by decreasing nutrient loss, reducing soil erosion, and improving water quality. These practices include conservation tillage (or no-till agriculture), cover cropping, and crop rotation (Sedjo and Sohngen 2012).

Recommendation 8: Re-establish western white pine and western redcedar.

Western white pine, which was once common in the Koksilah River landscape, is now rare due to the introduction of white pine blister rust to British Columbia in the early 1900s. Re-establishing western white pine enhances species diversity in the watershed, possibly contributing to resilience with respect to climate change due to its strong ability to sequester carbon and adapt to changing climatic conditions (Hines et al. 2013). Pruning to prevent the spread of white pine blister rust, and planting seedlings grown from blister rust-resistant parents are options for re-establishing western white pine (Hunt 2004). While Mosaic Forest Management (previously Island Timberlands, and TimberWest, respectively) has been including western white pine when planting in suitable sites in the Cowichan Valley (Pam Jorgenson, pers. comm.), other forest landowners and tenure holders are encouraged to explore the suitability of western white pine for their properties.

Western redcedar is rapidly declining on southern Vancouver Island due to successive years of drought following many years of overharvesting. Site selection for re-establishing cedar is challenging as mortality is widespread, even in riparian areas. Cool, moist sites with deep organic soils may provide the right growing conditions to help re-establish western redcedar in the landscape, and are therefore high priority areas for protection.

Recommendation 9: Re-establish natural drainage patterns at watershed and site scales.

Average road density throughout the watershed is approximately 4.5 kilometers per square kilometer (Pritchard et al. 2019). This value does not include other impervious surfaces such as driveways, parking lots, or building footprints in other parts of the watershed. Impervious surfaces contribute to an increase in overland flow during storms and subsequent surface erosion, reduced aquifer recharge, lower surface water quality. Provincial guidance indicates there may be a high level of concern for water quality and quantity (timing of flow) when road densities exceed 1.2 kilometers per square kilometer (MECCS and MFLNRORD 2019).

Overland flow can increase from 1% of rainfall in natural conditions to 25% in suburban areas (CVRD 2010 and references therein). Significant changes to streams occur when impervious surfaces exceed 10% and significant damage occurs when levels exceed 30% (CVRD 2010 and references therein). Since zoning bylaws in the Cowichan Valley Regional District allow for a maximum 10-30% impervious cover, with 30% permitted for Koksilah River and Kelvin Creek (CVRD 2010), significant damage to streams is an inevitable consequence of local government bylaws applicable to the watershed.

Logging roads, and other unpaved roads, while able to absorb some water, are still highly impervious contributing to surface flow. According to a technical report published by the US Forest Service, "[r]oads have three primary effects on hydrologic processes: (1) they intercept rainfall directly on the road surface and road cutbanks and affect subsurface water moving down the hillslope; (2) they concentrate flow, either on the surface or in an adjacent ditch or channel; and (3) they divert or reroute water from paths it otherwise would take were the road not present" (Gucinski et al. 2001). Wise et al. (2001) note that "[d]ecompacting the road surface...helps to restore the natural hillslope drainage paths since ditches, even when buried, can divert water along the road corridor".

Recommending specific actions to deactivate and decompact forestry roads requires specialized expertise that is beyond the scope of this report. Some general guidance provided by Gucinski et al. (2001) however is that what constitutes effective restoration will depend on an area's road development history and road geometry (i.e., patterns of roads across the landscape), on slope position, and on the specific environmental effects to be addressed. Gucinski et al. (2001) note that some effects may "result from road use, not from the presence of the road itself.

Photo 7. Road density is high with many roads constructed near streams, wetlands, and other watercourses.

Example Protected Ecosystem Network

Figure 3 illustrates an example of how the above recommendations can be applied at a small scale. For this scenario we have selected an area where forest, agriculture, and rural residential land uses intersect. While the area selected does exist and most features are in reality present, we did create some elements and embellish some scenarios to illustrate certain principles and practices.

The PAN and PLN (mapped in white) provide the large-scale structure around which the PEN is developed. In the first step, small-scale features requiring protection were identified (green). These include small forest patches and strips (e.g., shelterbelts) that contribute to connectivity, for example, linking the PAN to nearby watercourses. Other patches provide buffers between different land use zones like forestry and agriculture, while some were selected to enlarge PLN segments surrounded by high value forest observed during fieldwork (e.g., stands of old trees). A patch of old trees was also noted in the lands zoned for forestry, and was then placed in a protected node. Some riparian buffers identified in the PAN were also enlarged because during fieldwork, vegetation was noted that indicated moist riparian soils extend beyond the original 50 meter buffer.

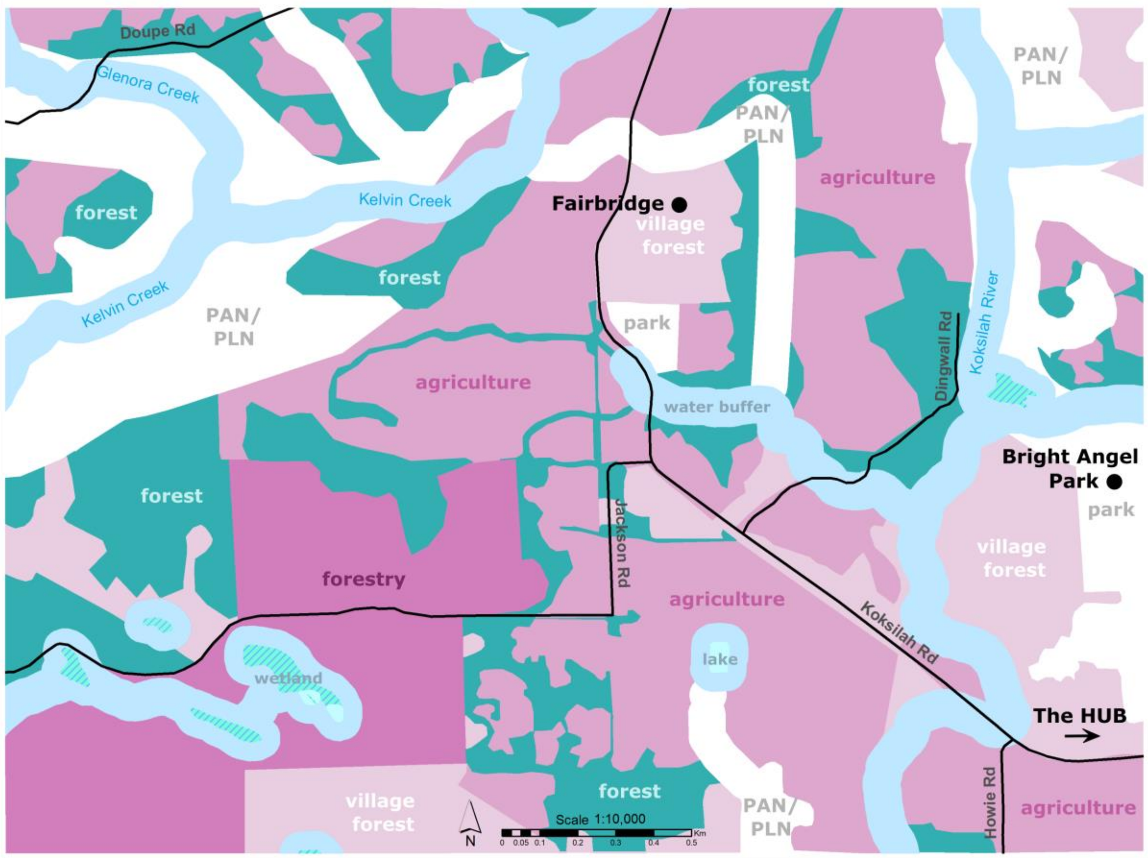
Next, three types of human use zones were identified based on current land use. While the new protected areas (i.e., green) work to link forest to agriculture to residential, additional practices occur in each of these zones to further contribute to connectivity and to build additional structure. For example, in forestry zones, full-cycle trees could be spaced throughout the harvest area, and several large snags and pieces of downed wood could be retained. In agriculture zones, shelterbelts could be extended and native plant strips could be established along field perimeters to facilitate pollination. In village forest areas, native plants could be encouraged, and the residents could initiate a bird and bat box program for the neighborhood.

Tables 2 and 3 summarize the recommended actions from the previous sections in two ways, by human use zone and by priority, respectively. In Table 2, some recommended actions are consistent across human use zones (e.g., restore riparian areas), while others are specific to the particular land use (e.g., restrict livestock from riparian areas). In Table 3, the same recommendations are categorized based on scale of impact (e.g., local versus landscape). Because this process was highly subjective, certain criteria were selected in an attempt to provide consistency.

Figure 3. Example Protected Ecosystem Network

Koksilah River Watershed

Example of Protected Ecosystem Network



A Protected Ecosystem Network (PEN) expands the network of protected areas by adding small, but important ecological features not previously captured by the Protected Area Network (PAN), or the Protected Landscape Network (PLN).

Areas in between are available for ecologically responsible human use--activities that occur within nature's limits.

water feature with buffer

protected areas (PEN)/ newly added features

protected areas (PAN & PLN)/ previously identified features

ecologically responsible human use areas

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Table 2. Recommended actions for each human use zone

Scale	Human Use Zone			
	Agriculture	**Forestry**	**Village Forest**	**All Zones**
PAN/PLN (watershed/ subwatershed scale)	Restore riparian areas	Abstain from harvesting in the PAN/PLN	Restore riparian areas	Restrict development in the PAN/PLN with special attention on riparian areas and high vulnerability aquifers
		Restore riparian areas		
		Rehabilitate unnecessary roads located in the PAN/PLN		
PEN (site scale)	Protect springs, small streams and other watercourses not captured in the PAN/PLN	Protect springs, small streams and other watercourses not captured in the PAN/PLN	Protect springs, small streams and other watercourses not captured in the PAN/PLN	Protect springs, small streams and other watercourses not captured in the PAN/PLN
	Restrict livestock, farm equipment from riparian areas	Restore small riparian areas	Restore small riparian areas	Restore small riparian areas
	Restore small riparian areas and protect from surface run-off	Abstain from clearcut harvesting	Retain forest patches	Provide for full-cycle trees by establishing tree protection laws/ incentives and in reserve patches created during subdivision
	Retain forest patches and existing shelterbelts	Retain 10-25% of dominant and codominant trees as full cycle trees	Retain all safe old growth trees	
	Retain all old growth trees	Retain all old growth trees	Retain dead trees in safe locations	
	Retain dead trees in safe locations	Retain 1 to 3 snags/ha and 6 large fallen trees/ha in harvest areas	In areas where dead trees pose a safety hazard, create high stumps (3-5m tall)	
	In areas where dead trees pose a safety hazard, create high stumps (3-5m tall)	Promote biodiversity by restricting use of herbicides and other pesticides	Hollow out logs to create den cover	
	Retain hollow logs as den cover	Establish western white pine and western redcedar where suitable	Install nest boxes and bat houses	
	Avoid further land clearing		Avoid further land clearing	
	Promote biodiversity by removing invasive plants (particularly in riparian areas) and establishing hedgerows, prairie strips, and new shelterbelts in open areas >250 meters wide		Promote biodiversity by removing invasive plants especially in riparian areas, reducing lawn cover, landscaping with native vegetation	
			Limit impervious surfaces	

Table 3. Prioritization tool for recommended actions

Localized effect	Broader effect
Provide for full-cycle trees by establishing tree protection laws/ incentives and in reserve patches created during subdivision Promote biodiversity by removing invasive plants especially in riparian areas, reducing lawn cover, landscaping with native vegetation Promote biodiversity by removing invasive plants (especially in riparian areas) and establishing hedgerows, prairie strips, and new shelterbelts in open areas >250 meters wide	Restore riparian areas Abstain from harvesting in the PAN/PLN Rehabilitate unnecessary roads located in the PAN/PLN Limit impervious surfaces Abstain from clearcut harvesting Avoid further land clearing Restrict development in the PAN/PLN with special attention on riparian areas and high vulnerability aquifers Protect springs, small streams and other watercourses not captured in the PAN/PLN Restrict livestock, farm equipment from riparian areas Restore small riparian areas and protect from surface run-off Retain dead trees in safe locations In areas where dead trees pose a safety hazard, create high stumps (3-5m tall) Hollow logs as den cover Retain 10-25% of dominant/codominant trees as full cycle trees Retain all old growth trees Retain 1 to 3 snags/ha + 6 large fallen trees/ha in harvest areas Do not use herbicides and other pesticides Establish western white pine and western redcedar where suitable

Information Gaps

While much has been learned about the Koksilah River watershed in this project, there are some information gaps that, if addressed, can contribute to a better understanding and management of the watershed. Recommendations to address these gaps include:

Revisit management plan for the Cowichan-Koksilah estuary. While much of the emphasis in this project has been on the mid and upper ecosystems of the Koksilah River watershed, the Cowichan-Koksilah estuary is an important part of the system. As described in the Phase 1 report (Pritchard et al. 2019), the Cowichan Estuary is one of the largest estuaries in BC providing valuable fish and wildlife habitat. However, the estuary has been significantly impacted by infilling, diking, pollutants, and the construction of a causeway associated with industrial, agricultural, and residential development. In 1986, management objectives were established by a provincial Order in Council to improve environmental protection (Lambertsen 1987); however, in the 34 years since it was enabled, the management plan has not be reviewed or amended. Due to the recent emphasis being placed on the watershed (i.e., the scoping for a Water Sustainability Plan), it seems appropriate to also revisit the management plan and provide updates (e.g., to zoning) that reflect current concerns and priorities. Revisiting this plan would also allow for more meaningful consultation with Cowichan Tribes, which was minimal when the original plan was prepared.

Photo 8. The Cowichan-Koksilah estuary has been extensively modified by industry, agriculture, and residential development (Photo credit: Lorne Duncan).

Conduct a current condition assessment of aquatic ecosystems in the Koksilah River watershed. The Province of BC has developed, as part of its cumulative effects program, an interim assessment protocol for measuring health of aquatic ecosystems (MECCS and MFLNRORD 2019). This protocol has been applied to watersheds in Howe Sound (MFLNRORD 2018) and in the Elk Valley of the East Kootenays (AEET 2018). Indicators include riparian disturbance, stream crossing density, road density within 100m of a stream, road density of steep slopes, and equivalent clearcut area. Results for these indicators can be used to establish further information gaps and possible management actions for each sub-watershed.

Assemble more accurate data. While publicly available data was relied on for this project, some landowners, in particular Mosaic Forest Management (formerly TimberWest, and Island Timberlands), have collected more accurate data over the years. Access to this data would help other landowners in the community better understand their watershed and assist restoration activities. In particular, the community would benefit from data on karst formation locations, stream classification, fish and wildlife, and forest and vegetation inventory.

In addition, in the Phase 1 Report (Pritchard et al. 2019) the following work was suggested to better partition and attribute cause for the decline in summer low flows:

Regional hydrologic analysis to put the Koksilah flow regime in context. It would be helpful to place the Koksilah watershed within a regional analysis to understand the severity of changes to its hydrologic regime.

Improved understanding of factors affecting base flow. Pressures on groundwater recharge, including the potential for cumulative effects, need to be better understood given the likely significance of groundwater to the Koksilah River's base flow (i.e., summer low flow). An assessment of the hydraulic connection between the Koksilah river and surrounding aquifers, and on the impacts of seasonal groundwater withdrawals, could help to establish aquifer budgets and improve understanding of factors affecting summer river flow.

Improved understanding of summer surface-water balance. The pressures on the summer availability of water at the hydrometric station should be better quantified and partitioned. It is recommended that assessment components include a GIS analysis and field assessment to clarify the surface water demand above the Koksilah river hydrometric station, and a more detailed analysis of the role of forest management and road density on rainfall-runoff dynamics. (This step may benefit from application of the Tableau Database Tool which facilitates separating base flow and storm flow in rivers, and estimating potential water-withdrawals within a specific catchment on a monthly or seasonal basis using water license and groundwater well location/type information.)

Conclusions

This report concludes the ecosystem-based assessment of the Koksilah River watershed. In this project, we described the original character and current condition of the watershed, and key pressures affecting ecosystem health. We presented a recommended design and principles for establishing a network of protected areas aimed at restoring ecological integrity across the watershed. We also recommended actions to assist with the recovery of ecological integrity at multiple spatial scales, and within various land use contexts. While a more complete dataset would have enabled greater precision in designing the network of protected areas, the rationales given for including each feature will help to ensure that site-level decisions are consistent with the intent of the design: to restore ecological integrity at multiple spatial scales, and across the watershed.

This study has revealed the rapid change in ecological condition of the Koksilah watershed-- from an old forest landscape to one that is highly developed—and its consequent decline in health. We conclude that old forest is under-represented in the watershed, and that increasing the amount of mature and older forest may recover healthy watershed functions. Implementing the recommended network of protected areas can help accomplish this. Growing pressures such as climate change and human population growth require that actions be taken immediately.

While we provide several recommendations in this report, there is one action that is particularly important: protect and restore riparian areas on all streams, wetlands, lakes, and springs, regardless of their size. This begins with protecting all existing riparian forests and their structures by establishing wide buffers, removing roads and structures from riparian ecosystems, and restoring disturbed riparian ecosystems.

An economic analysis is outside the scope of this project. The dramatic difference between the ecological character of the Koksilah watershed and its current condition, along with a historical review of watershed land use, however, leads us to conclude that a different economic model based on less intensive land management and an innovative approach to greater employment from fewer resources would greatly benefit the Koksilah River watershed. There is not one land use alone that is responsible for the changes in the watershed, hence there is a role for all land owners and managers to participate in its recovery. The level of responsibility of each landowner or manager, however, should be proportionate to their footprint as a land user—that is, the size, intensity, and potential for their land use to foreclose other land use opportunities, especially those most directly tied to human health.

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